

PATENT SPECIFICATION

755,738



Date of Application and filing Complete Specification: Nov. 24, 1953.

No. 32561/53.

Application made in United States of America on April 7, 1953.

Application made in United States of America on April 7, 1953.

Complete Specification Published: Aug. 29, 1956.

Index at acceptance:—Classes 2(2), E(1B:6DX); 2(5), P4(A:D3B1:K7:P6X:T1X), P4T2(D:E:X), P7A, P7D1(A:B), P7D2A1, P7K(4:7:10), P7(P6X:T1X), P7T2(D:E:X), P10(A:D1A:K7:P6X:T1X), P10T2(D:E:X); and 140, A2(F:G:X), E1(D:H).

COMPLETE SPECIFICATION

Improvements in or relating to the Surface Treatment of Polyethylene-Containing Structures

We, E. I. DU PONT DE NEMOURS AND COMPANY, a corporation organised under the laws of the State of Delaware, United States of America, of Wilmington, State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to treating the surfaces of polyethylene-containing structures, such as films, to improve the adhesion properties thereof, for example, to promote the adhesion thereto of printing inks and various other materials.

In general, polyethylene films are tough, semi-transparent, resistant to many chemicals, exhibit a high degree of moisture vapor impermeability, permit the passage of oxygen, and are heat-sealable. Because of this combination of properties, polyethylene films are highly useful for packaging and wrapping a great variety of materials such as chemicals, fresh produce, dried milk, textiles and hardware. Probably the only troublesome disadvantage of polyethylene film for use in the packaging field is the fact that standard aniline and rotogravure printing inks employed for printing various cellulosic films, such as regenerated cellulose and cellulose acetate films, do not adhere satisfactorily to the surface of the film. Generally, any indicia, such as trade marks, advertising indicia or recipes imprinted upon a surface of a polyethylene film with standard oil or lacquer type inks employed for printing cellophane film are easily smeared or rubbed off by the normal abrasions suffered by packages during shipping and handling. The word "Cellophane" is a registered Trade Mark. Hence, in order to obtain satisfactory adhesion between a dried ink and a polyethylene film surface, it is necessary to employ a specially compounded ink or modify the

film surface to promote improved ink adhesion.

Although printing inks compounded particularly for printing on polyethylene films have been developed, the use of most of these inks requires modification of standard printing processes; and the preferred approach is treatment of the polyethylene film surface to promote adhesion of standard oil and lacquer type inks.

An object of the present invention is to provide a process of treating the surface of a polyethylene structure, e.g., film, to improve adhesion of standard printing inks, i.e., promote adhesion of standard aniline and rotogravure inks employed in printing on cellophane film. Another object is to provide a process of treating the surface of a polyethylene film to improve adhesion thereof to various other materials, such as metals, paper, nitro-cellulose coatings, and other polymeric coatings, e.g., nylon, and polyethylene terephthalate. A further object is to improve the adhesion of polyethylene film to itself and other material, when using commercial adhesives. A still further object is to provide a process of treating the surface of a polyethylene film to improve adhesion thereto of dried ink impressions and not impair the transparency of the film. A still further object is to provide a polyethylene film having modified surface characteristics such that dried ink imprints on the surface will not rub off when tested in accordance with the various tests described hereinafter.

According to the invention, a process is provided of treating the surfaces of a polyethylene-containing structure, such as a film, to improve the adhesion properties thereof, which comprises subjecting the structure as it is extruded at a temperature between 150° C. and a temperature below the degradation temperature of the polyethylene into a bath,

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to the action of an agent selected from the following:— aqueous solutions of the halogens, the hydrogen halides, hydrogen peroxide, nitrous acid and alkaline hypochlorites; concentrated nitric acid; and mixtures of concentrated nitric and sulfuric acids; said agents being maintained at a temperature in the range of 25° C. to 95° C. Said treatment is preferably carried out in the presence of ultraviolet light, and is also preferably effected at a temperature in the range of 25° C. to 65° C.

In the normal process of extruding molten polyethylene into film form, a molding powder or flake of polyethylene is fed continuously into a melt extrusion machine, and the molten film continuously extruded through a slot orifice and through an air gap vertically downward into a quench bath maintained at a temperature from 25°—95° C., preferably from 30°—60° C. Usually, the polyethylene is extruded from a melt maintained at a temperature within the range from 150° to 325° C. Tubing is usually extruded from a melt at a temperature within the range from 150°—200° C., whereas film is extruded at a temperature within the range from 250°—325° C. An alternative process of forming a polyethylene film comprises milling molten polymer on closely-spaced calender rolls to form a film which is conducted vertically downward into a quench bath. In either of these general methods of forming a polymeric film, the space between the point where the molten film leaves the slot orifice or the last calender roll and the point where the molten film enters a quench bath will hereinafter be termed the "air gap." During passage through the air gap, the film is merely permitted to pass uninhibited through the atmosphere, and this provides for some superficial cooling. Generally, the length of the air gap ranges from about 2" to as long as 15" in some cases.

The process of the present invention is most conveniently carried out by subjecting freshly formed film to the action of the herein specified agents contained in the quench bath which, as pointed out, immediately follows the film-forming step in the normal processes of polyethylene film manufacture. Hence, the process of this invention may be carried out with substantially no modification of existing film-forming apparatus. Preferably, the quench bath is subjected to agitation by mechanical means or by employing sonic or supersonic waves, this agitation increasing the rate of action of the agents of this invention upon the polyethylene film. The rate of action may also be accelerated by exposing the film to ultra-violet light having a wave length no greater than 3600 ÅU during treatment in the quench bath. In the continuous production of polyethylene film treated in accordance with this process, the time of treatment in the quench bath should not exceed 4 seconds.

Any agent or mixture of agents which would

not impair the efficacy of the process, selected from the following:— halogens and the corresponding acids, i.e., chlorine, bromine, iodine, fluorine, hydrochloric acid hydrobromic acid, hydroiodic acid, and hydrofluoric acid, hydrogen peroxide, nitrous acid, alkaline hypochlorites, concentrated nitric acid and mixtures of concentrated nitric acid and sulfuric acid, may be employed in the quench bath for purposes of this invention. The agents may be employed in the quench bath in high concentrations, for example, concentrated aqueous solutions of the halogens or halogen acids; and for rapid action, these high concentrations are preferred. Hydrogen peroxide has been employed in concentrations ranging from 0.24% to 32%, by weight of the total bath; and higher and somewhat lower concentrations are entirely operable. The same applies to the alkaline hypochlorites, but about 30% or higher is preferred. When nitric acid or mixtures thereof with sulfuric acid are used, the concentrated acids are preferred. After quenching the film, it is necessary to conduct it into an alkaline bath such as an aqueous solution of sodium hydroxide, or aqueous sodium bicarbonate containing about 2% hydrogen peroxide, to neutralize the agent in the quench bath; and thereafter the film is washed with water.

For obtaining the desired physical characteristics in the polyethylene film, the quench bath is normally maintained at a temperature between 25° and 65° C. However, if the physical properties of the resulting film are not impaired or reduced below the minimum requirements for particular end uses, the use of higher quench bath temperatures, e.g., up to 90—95° C., permits shorter treatment times. In general, quench bath temperatures substantially higher than 65° C. do not sufficiently quench the film; and with slower cooling effected by higher bath temperatures, the polyethylene film formed is generally more crystalline and, consequently, has lower strength properties, lower flexibility and transparency, and the bond strengths of heat seals are considerably lower. Hence, quenching bath temperatures should normally be maintained below 65° C. Furthermore, it should be emphasized that quench bath temperatures higher than 60—65° C. are not recommended when aqueous solutions of the gaseous halogens or halogen acids are employed because considerable quantities of the gases are lost to the atmosphere as a result of desorption.

The following examples of specific preferred embodiments further illustrate the principles and practice of this invention.

Polyethylene film extruded from a melt was permitted to pass through an air gap of 10" and then into a quench bath containing an agent of the present invention. Table I summarizes the conditions of treatment and the results obtained with respect to film printability.

TABLE I

Quench Bath Composition	Temp. Quench Bath °C.	Melt Temp. °C.	Time in Quench Bath seconds	Printability
Saturated chlorine gas in water with shroud covering film and bath	50	300	less than 0.65	Excellent
Aqua regia (3 parts by weight concentrated hydrochloric acid and 1 part conc. nitric acid)	40	300	less than 0.65	Excellent
Conc. hydrochloric acid	68	300	1.7	Excellent
0.24% aqueous H ₂ O ₂	42	232	3.33	Good
3.57% aqueous H ₂ O ₂	30	232	2.86	Good
31.8% aqueous H ₂ O ₂	45	232	2.77	Excellent
31.8% aqueous H ₂ O ₂	90	232	1.43	Excellent
30% aqueous sodium hypochlorite	30	288	3.33	Excellent
30% aqueous sodium hypochlorite	90	288	1.0	Good
Conc. nitric acid	78	292	1.43	Excellent
Conc. H ₂ SO ₄ /Conc. HNO ₃ (9 lbs./42 lbs.)	90	288	less than 0.4	Excellent

In evaluating the printability, i.e., the strength of the adhesive bond between the dried ink and the treated polyethylene film surface, a number of tests were employed (5 in all); and, on the basis of the results of all of the tests, the films were rated either acceptable or not acceptable and, if acceptable, either excellent or good. Four different inks were employed to print the treated surfaces of polyethylene films, and each printed sample was evaluated in accordance with each of the five tests which will be described hereinafter. The inks employed were as follows:

- 15 No. 1 Aniline Cellophane Ink (Bensing Bros. and Deeney, No. W-400).
- No. 2 Aniline Polyethylene Ink (Interchemical Corporation, No. PA-Red).
- 20 No. 3 Rotogravure Cellophane Ink (Bensing Bros. and Deeney, No. G-1037).
- No. 4 Rotogravure Polyethylene Ink (Interchemical Corporation, IN-Tag-Red, GPA Red).

25 In preparing the printed samples of polyethylene film, the ink was applied with a commercial ink spreader which comprised a steel rod having fine wire wrapped around the rod. The spreader produced a multiplicity of fine lines. The ink was dried for three minutes at 70° C. and thereafter permitted to cool to room temperature. Each sample was then tested in accordance with each of the following tests, and the amount of ink rubbed off and/or removed was noted:

1. *Rub Test*—The inked polyethylene surface was rubbed ten times against a hard white paper.

2. *Scratch Test*—The back of a fingernail was rubbed across the inked surface.

3. *Flex Test*—The film was held between thumb and forefinger (2" apart) and flexed vigorously.

4. *Pressure-Sensitive Tape Test*—A pressure sensitive tape was pressed against the printed surface, and then pulled off.

5. *Twist Test*—The printed form was folded once and then again in a direction perpendicular to the first fold. The folded ends were then twisted once around, and thereafter the film surface was examined for smearing and/or cracking of the dried ink.

Although the present process is employed primarily for treating the surface of a polyethylene film in order to produce a film which may be successfully printed with standard oil or lacquer type inks, e.g., aniline or rotogravure inks employed for printing on cellophane film, the present invention may be employed to modify the surface of a polyethylene film which is to be printed with inks which are especially modified for printing upon a polyethylene film surface. The net result is an even further improvement in the adhesive bonds between the dried ink and the polyethylene film surface. The present invention further provides for the preparation of a polyethylene film which is more readily adherent to metals, papers, and various coat-

ings, such as those of nitrocellulose; polyamides, e.g., polyhexamethylene adipamide, polyhexamethylene sebacamide, N-methoxymethyl polyhexamethylene adipamide and other polyamides defined in U.S.P. 2,430,860, and interpolyamides defined in Patent No. 557,544; polyethylene terephthalate; polyvinyl acetals such as polyvinyl butyral, ethyl cellulose; vinyl acetate-vinyl chloride copolymers; vinylidene chloride copolymers, chlorinated rubbers. Furthermore, polyethylene film treated by the present process is more readily adhered to itself and other base materials by using commercial adhesives, e.g., standard adhesives employed for sealing cellophane.

The process of this invention may also be employed for treating the surface of various films fabricated from copolymers of ethylene with various other polymerizable materials, e.g., isobutylene, vinyl acetate, styrene, vinyl chloride.

The outstanding advantage of the present process is that it provides a readily applicable and rapid method of improving the adhesion of a dried printing ink to the surface of a polyethylene film. The process may be readily combined with a necessary step of extruding or calendering molten polyethylene into film or tube form, and the additional apparatus required is inexpensive and easy to install.

Our Specification No. 738,474 describes and claims a process for treating polyethylene surfaces, such as films, to improve the adhesion properties thereof, which comprises subjecting said surfaces to the action of ozone at a temperature not below room temperature in the presence of a reaction accelerator agent selected from the group consisting of the halogens; the hydrogen halides; and nitrous oxide.

Said treatment is preferably carried out in the presence of ultraviolet light, and is also preferably effected at a temperature in the range of 150° to 325° C.

What we claim is:—

1. A process for treating the surfaces of a polyethylene-containing structure, such as a film, to improve the adhesion properties thereof, which comprises subjecting the structure as it is extruded at a temperature between 150° C. and a temperature below the degradation temperature of the polyethylene into a bath, to the action of an agent selected from the following: aqueous solutions of the halogens, the hydrogen halides, hydrogen peroxide, nitrous acid and alkaline hypochlorites; con-

centrated nitric acid; and mixtures of concentrated nitric and sulfonic acids; said agents being maintained at a temperature in the range of 25° C. to 95° C.

2. A process for treating the surfaces of a polyethylene-containing structure, such as a film, to improve the adhesion properties thereof, which comprises subjecting the structure as it is extruded at a temperature between 150° C. and a temperature below the degradation temperature of the polyethylene into a bath, in the presence of ultraviolet light, to the action of an agent selected from the following: an aqueous solution of the halogens, the hydrogen halides, hydrogen peroxide, nitrous acid and alkaline hypochlorites; concentrated nitric acid; and mixtures of concentrated nitric acid and sulfonic acid; said agents being maintained at a temperature in the range of 25° C. to 95° C.

3. A process according to claim 1 or 2, in which said treatment is carried out at a temperature in the range of 25° C. to 65° C.

4. A process according to any of claims 1 to 3, in which said structures are immersed in an aqueous bath containing said agent, said bath preferably being agitated.

5. A process according to claim 4, in which a polyethylene-containing film is continuously formed and is continuously passed through said bath.

6. A process according to any of claims 1 to 5, in which a treated surface is thereafter imprinted with a printing ink.

7. A process according to any of claims 1 to 5, in which a treated surface is thereafter coated with a coating composition.

8. A process according to any of claims 1 to 5, in which a treated surface is thereafter laminated to a base material.

9. A process according to any of the preceding claims, in which said structures comprise polyethylene copolymers.

10. A process for treating the surfaces of polyethylene-containing structures, such as films, to improve the adhesion properties thereof, substantially as hereinbefore described.

11. Polyethylene-containing structures, such as films, having surfaces with improved adhesion properties, whenever produced by the process according to any of the preceding claims.

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